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THESIS

AN OPTIMIZATION OF A NETWORK STRUCTURE FOR A BRIGADE LEVEL MILITARY ORGANIZATION

by

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September 2000

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Networking is vital for all computer-using organizations. No computer can be thought of as a stand-alone computer. Organizations need to analyze and develop the optimal network structures with consideration of their hierarchical structures. Their needs are to be analyzed as well. The topology and the technology of the network to be developed needs to be considered and then planned

This thesis presents the different types of network topologies and network technologies .The Structure of a Brigade is analyzed and different topology combinations for different levels hierarchical structure are analyzed. The flow of the network traffic and network load is optimized using Extend v4, a general purpose simulation tool.

The results show that the optimal network topology for the subject Brigade is Star topology at all levels. The type of technology to be used is Fiber Distributed Data Interface technology.

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AN OPTIMIZATION OF A NETWORK STRUCTURE FOR A BRIGADE LEVEL MILITARY ORGANIZATION

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ABSTRACT

Networking is vital for all computer-using organizations. No computer can be thought of as a stand-alone computer. Organizations need to analyze and develop the optimal network structures with consideration of their hierarchical structures. Their needs are to be analyzed as well. The topology and the technology of the network to be developed needs to be considered and then planned.

This thesis presents the different types of network topologies and network technologies .The Structure of a Brigade is analyzed and different topology combinations for different levels hierarchical structure are considered. The flow of the network traffic and network load is optimized using Extend® v4, a general purpose simulation tool.

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I. INTRODUCTION

A. PURPOSE

The purpose of this thesis study is to design and develop a network structure for an imaginary Brigade Level Military Organization. The network structure will be developed by considering different network topologies and network technologies. The resulting network structure will be tested in terms of network traffic by using a general purpose simulation tool called Extend® version 4.0.

B. BACKGROUND

1. The Problem

I have worked as a Communications Platoon leader of the Communications Company of a Brigade in my country. I have observed the different types of communications such as radio, telephone, courier, tele-typewriter. They seemed to be working fine but there were a lot of computers in different units of the Brigade. These were all stand-alone computers with no connections between each other.

After coming to United States and studying Information Sciences and technology, I acquired a new vision of communications system for our brigades. The main backbone of the new system will be formed of computers and a network structure.

To realize this new vision, I had to consider the structure of the Brigade together with appropriate network structures for all the sub-units.

2. The Solution

Today networking is vital for all computer-using organizations and I thought it was high time a network was to be installed for all Brigades in my country. For this

reason I figured out the general appearance of the structure of a Brigade in my head. I drew a picture of the pipes of communications within and to outside of the Brigade. I also overviewed different network topologies and technologies so that I can apply them to the new communications' system of the Brigade. As a result there will be a connection between all computers within the Brigade with no stand-alone computers.

After generating a final picture of the network, I decided to optimize the resulting network by using a simulation tool called Extend®. In the optimization part, I considered five different types of traffic which are e-mail, e-mail with attachments, command level audio-visual teleconferencing, network management applications and World Wide Web surfing.

There is a fiber backbone and a separate twisted-pair copper backbone within the brigade for networking purposes. The main backbone will be the fiber backbone providing 100 megabytes of bandwidth and the twisted pair will be considered as auxiliary. These two backbones are used in the network optimization process.

As a result of the network optimization, the network will be able to handle the different types of traffic within the Brigade area. The message delay times change with respect to network load at different times.

3. What Happens if the Problem is not Solved

The current means of communications will still be used. There will be a deficiency in communications speed. The old systems do not provide any means for networked computer communications. The computers currently used will be continued to be used as stand-alone computers. The communications will still be done using walking couriers, telephone, tele-typewriters, radios.

C. OUTLINE OF REMAINING CHAPTERS

The current conditions of communications and the need for networking within the brigade and the significance of Local Area Networks is the topic of Chapter II. Different networking topologies are covered together with some sample technologies using these topologies. The simulation tool Extend® is covered together with the proposed network model in Chapter III. A brief description of the structure of the Brigade is also covered. The results and findings of the model and network simulation are covered in Chapter IV. Chapter V recommends ways to implement the proposed network structure and provides topics for follow-up studies.

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II. BACKGROUND

A. CURRENT CONDITIONS

The Brigade, which is the subject of this study, is located in one of the metropolitan cities of the country. It is an armored brigade with four tank battalions, four mechanized infantry battalions, the support units, the command support units and the command service support units.

The current means of communications is provided by a signals company. The main means of communication are telephony, written messages via teletypewriters, radio communications including FM and HF type radio devices, and hand typed written messages delivered by courier. All of these are provided by different sub-units of the signals company.

The brigade is a sub unit of the Corps , thus has to be in some radio communications with the Corps and the Army level. All the communications personnel are trained by the Signals Company. The Company has a company commander, 4 platoon leaders and 35 NCO's and 150 enlisted personnel working at various levels. Everyday a motorized courier goes to the Corps Command for the necessary transfer and exchange of messages.

The courier is considered to be the most reliable form of messaging provided that the personnel are reliable and there are no dangers which can affect the route of the courier. The second reliable means is the telephony within the brigade itself as well as the outer world. Then comes the various radio communications which has specific times to be on and off.

All these systems seem to be working well but they are kind of outdated for the 21st century. Some of the devices used for communications are old and outdated but there is a renovation process going on and they are in a modernization process to be completed by 2010. But they still require trained technical personnel and maintenance. Also a communications infrastructure is being built and the result of this study will be compatible with that infrastructure. The devices used are transportable and some of them are mounted on vehicles.

The messaging is done using teletypewriters and a cryptography device. This performs its function but it is vulnerable to attacks. The computers can replace teletypewriters and can provide better means of communication in terms of speed and reliability. But they will still be vulnerable in terms of communications security.

The telephony is the most commonly used way of communication. But the infrastructure of cabling is old and needs to be renewed. A Pbx provides the lines from the outer world into and out of the brigade. Bad weather conditions can affect the telephony and the radio communications negatively.

There are PCs used for different purposes such as typing, and presentation purposes. There is no connection between the PCs such as a network, they are all stand-alone. Talented enlisted personnel are available in the sub units the brigade and they can help establish a network.

B. NEED FOR NETWORKING WITHIN THE BRIGADE

The new network will provide at least three PCs at company level. These PCs will be connected to each other using the appropriate topologies such as star topology,

ring topology and bus topology. The fiber-optic infrastructure can be used for this purpose. These lowest level topologies will then be connected to battalion level network structure. The battalion level will be connected to the brigade level network. The battalions' and the brigades' headquarters will be included with separate workstations within the network structure. The general hierarchical structure of the brigade is provided in the appendix A.

The network has to be built efficiently so that it wouldn't require replacements within the near future such as 20 years. That is why the proposed network should provide sufficient bandwidth. The current need might not be for a high bandwidth but if it is considered that currently only text is transmitted. The future network should provide sufficient bandwidth for figures to images, to voice communication, to live teleconferencing and even digital maps.

The Personnel training will be an issue. But once a group is trained, they will train another group and then it will have a domino effect .As a result every responsible person will learn what he needs to do to perform his mission.

This study will first develop ideal network topologies and then test to optimize the whole network structure for the brigade. The optimization will be in terms of the flow of network traffic.

The remaining of this chapter first goes over the general topics in networking and then explains different network topologies and sample current network technologies used.

C. THE GROWTH OF NETWORKING

There is a continuous growth of networking. Few people were able to access to a network twenty years ago. Computer communication has become a part of our daily life. Few people in the U.S. have no e-mail account. Networking is used in many aspects of businesses from the advertising and billing to production and accounting. Schools provide their teachers and students with on-line libraries from all over the world. Almost all of the governmental offices make use of computer. In short, computer networks are used everywhere.

The continued growth of Internet is one of the most interesting and exciting events in networking. Two decades ago, the Internet was a research project that involved a few dozen sites . Today, people in many different countries, communicate with one another via Internet. The Internet connects most corporations, schools and governmental offices. Most people have dial-in connections to the Internet from their homes. Even newer technologies such as DSL cable modem,T-1 and ISDN ,are being invented to provide faster connection with a higher bandwidth. As a result networking has become an industry which made telecommuting possible for individuals.

D. COMPLEXITY OF THE NETWORKING SYSTEMS

Networking can especially seem confusing to a beginner since there are various underlying theories created by various companies. These theories usually are not compatible with one another. In fact, there are some attempts to define conceptual models

that can be used to explain the similarities and differences among the network hardware and software systems. But the technologies are diverse and changing rapidly.

Thus the models are either simplistic so that they do not distinguish among details or they are so complex that they do not help simplify the subject.

E. THE SIGNIFICANCE OF LOCAL AREA NETWORKS

Local Area Networks have become the most commonly used form of networking. These are privately owned networks within a single building, a presidio or a campus up to a few kilometers in size. They are mostly used in many organizations mainly to share resources such as printers and to exchange information. The LAN, which is going to be developed as a result of this study ,is going to serve mainly for these purposes as well.

The LANs are restricted in size and as a result they are inexpensive and widely available. But the main reason for the high demand of LANs is a fundamental principal of networking called *locality of reference.* (Computer Networks and Internets by Douglas E. Comer p.76-77)This principle states that communication among a set of computers follows two patterns: The first pattern states that if a pair of computers communicate once, they are likely to communicate again more commonly and then periodically. The second pattern states that a computer tends to communicate with computers that are nearby and close to its location.

F. LAN TOPOLOGIES

Many LAN technologies have been invented. That's why it is important to know how specific technologies are similar and how they are different. To distinguish between

these technologies, each network is classified into a category according to the general shape of the network or better called as *topology* of the network. The mostly used types of networks are the following. (Computer Networks and Internets by Douglas E. Comer p.77-80)

1. Star Topology

In a star topology, all the computers are connected to a central point. This central point is generally called a *hub*. The general appearance of the computers in a star topology is similar to the spokes of a wheel. The center or hub is an electronic device that accepts data from a sending computer and delivers it to the appropriate destination. The distance between each computer in the network does not have to be the same. Instead the hub is located at a place separate from the computers and the computers are attached to it. For instance the computers can reside in the individual offices of a company whereas the hub resides in a location which can only be accessed by the networking staff.

A Star topology helps to protect the network from damage to a single cable because each cable connects only one machine. But star topology requires more cables to connect the computers to the network.

The following figure in the following page illustrates the general appearance of a *star* topology.

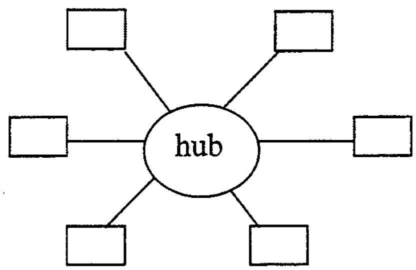

Figure 2.1Star Topology

2. Ring Topology

In a *ring* topology, the computers are connected in a closed loop. A cable connects the first computer to the second computer while another computer connects the second computer to the third computer and so on until a cable connects back to the first computer. The name ring arises since the computers can be arranged in a circle.

It is also essential not to misunderstand the ring as if it refers to the physical orientation. The term *ring* refers to the logical connections among computers. The computers and connections need not be arranged in a circle. The cable between the computers connected may follow a hallway or rise vertically from one floor of a building to another. Also, a computer far from the others may be connected to the ring using the same physical path for connection.

The ring topology makes it easy for computers to coordinate access and to detect whether the network is operating correctly. However the entire ring is disabled if one of the cables between any of the computers is cut.

The following figure illustrates the general appearance of a *ring* network.

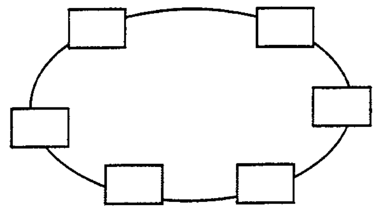

Figure 2.2 Ring Topology

3. Bus Topology

In *Bus* topology, the network consists of single, long cable to which the computers attach. Each computer attached to the bus can send a signal down the cable and all other computers receive the signal. Since all computers attached to the bus can sense an electric signal, any computer can send data to any other computer. As a result of this situation all computers must coordinate to ensure that only one computer sends a signal at a time or the result will be a chaos.

A bus topology requires fewer wires than a star, but has the same disadvantage as the ring networks; the bus network is disabled if someone accidentally cuts the main cable.

The following figure in the following page illustrates the *bus topology*.

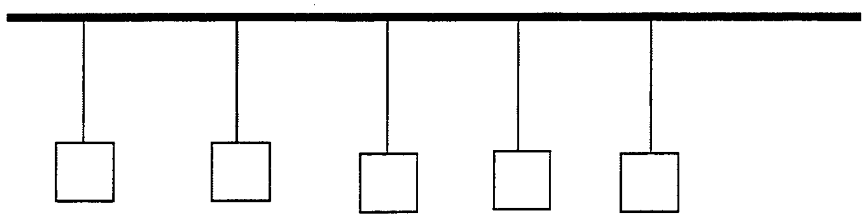

Figure 2.3 Bus Topology

G. SOME SAMPLE TECHNOLOGIES USING THESE TOPOLOGIES

1. Ethernet

Ethernet is a well-known and widely used network technology that employs bus topology. It consists of a single coaxial cable called the *Ether (* Computer Networks and Internets, Douglas E. Comer p.79) in its original version to which multiple computers were connected. Engineers use the term *segment* to refer to the Ethernet coaxial cable. A given Ethernet segment is limited to 500 meters in length, and a minimum separation of 3 meters is required between each pair of connections.

Since Ethernet uses a bus topology, it is required for multiple computers to access to a single medium. A sending computer sends a signal towards both ends of the shared cable. It is important that the other computers should wait while one computer is sending bits. The sending computer has the exclusive right of sending, the others must wait.

The mechanism used to coordinate transmission in an Ethernet LAN is called the *Carrier Sense Multiple Access.* This is kind of a coordination scheme to prevent

collisions used by all participating computers attached to Ethernet. This scheme uses electrical activity to determine status. When no computer is sending frames, the ether does not contain any signals whereas a sending computer transmits electrical signals used to encode bits. Thus, to determine whether the cable is currently being used , the computers can check for a carrier. If no carrier is present the computer can send the bits. The technical name of checking for a carrier wave is called *carrier sense* and the idea of using the presence of a signal to determine when to transmit is called *Carrier Sense Multiple Access(CSMA)*

CSMA can not prevent all the conflicts in sending signals. For instance two computers can have a frame ready to send at both ends of a cable.. When they check for a carrier simultaneously, they can find the cable idle and begin transmitting. As a result collision occurs. Although the collision does not harm the hardware, it produces a garbled transmission that prevents both frames sent by the computers from being received correctly. To ensure that no other station is transmitting simultaneously, the Ethernet standard requires a sending station to monitor signals on the cable. If the signal on the cable differs from the signal the station is sending, it means that a collision has occurred. Whenever a collision is detected, a sending station immediately stops transmitting. Technically monitoring a cable during transmission is known as *Collision Detect* and the Ethernet Mechanism is called *Carrier Sense Multiple Access with Collision Detect(CSMA/CD).* Not only does this mechanism detect the collisions, but it also recovers from collisions. After a collision occurs, a computer must wait before the cable becomes idle to transmit another frame. If the computers begin to transmit as soon as the ether becomes idle, another collision will occur. To avoid multiple collisions, Ethernet

requires each computer to delay after a collision before attempting to retransmit. The standard specifies a maximum delay, *d,* and forces each computer to choose a random delay of shorter than *d*. The computer which chooses the least amount of delay will proceed to transmit and the network will return to normal operation.

2. IBM Token Ring (An Example for Ring Networks)

As stated earlier, a LAN using ring topology connects computers in a logical loop. The LANs using ring topology use an access mechanism called *token passing* and the resulting networks are called *token passing ring networks,* abbreviated *token ring.* A token ring operates as a single, shared medium. When a computer needs to send data, the computer must wait for permission before it can access the network. Once it obtains the permission, the sending computer has complete control of the ring-no other transmissions occur simultaneously. As the sending computer transmits a frame, the bits pass from the sender to the next computer, then to the next computer and so on until the bits pass completely around the ring and arrive back at the sender.

3. FDDI (Another Example for Ring Networks)

Since a computer attached to a ring must pass bits of a frame to the next computer, failure of a machine can disable the entire network. Token ring hardware is usually designed to avoid such failures. However, most token ring networks cannot recover from a broken connection such as those that result if the cable connecting two

computers is accidentally cut. Some ring network technologies have been designed to overcome severe failures. *Fiber Distributed Data Interconnect* (FDDI) is a token ring technology that can transmit data at a rate of 100 million bits per second, eight times faster than an IBM token ring network and ten times faster than original Ethernet. To provide such high data rates, FDDI uses optical fibers to interconnect computers instead of copper cables.

FDDI also uses redundancy to overcome failures. In an FDDI network there are two complete rings one of which is used to send data when everything is working correctly and the other is used only when the first ring fails. The rings in an FDDI network are called *counter rotating* because data flows around the second ring opposite of the data which flows around the main ring. When a failure occurs that breaks the ring, stations adjacent to the failure automatically reconfigure, using the second ring to bypass failure.

4. ATM (An Example for Star Networks)

The telephone companies have developed a networking technology with the purpose of providing high bandwidth called *Asynchronous Transfer Mode(ATM).* The basic element of an ATM network is a central switch to which multiple computers can connect. The following figure illustrates the general appearance of an ATM network. In an ATM network, one or more interconnected switches form a central hub to which multiple computers attach. Unlike bus or ring topologies, a star network does not propagate data to any computes other than the communicating pair. The hub receives

incoming data directly from the sender, and transmits outgoing data directly to the receiver. The star topology makes an ATM network less dependent on the connections to the individual computers than a network that uses a ring topology. If the connection between a computer and the switch breaks, only that computer is affected. Since ATM is designed to provide a higher bandwidth, a typical connection between a computer and an ATM switch operates at a speed of 155 Mbps or faster. Thus the connection between a computer and the switch uses optical fiber instead of copper cable.

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III. METHODOLOGY

A. EXTEND SIMULATION SOFTWARE

Extend ® version 4.0 simulation tool was used to create the model. Extend is claimed to be "the simulation software for the next millennium" (Extend version 4.0, User Manual) . It is a general purpose, dynamic, graphical simulation tool that enables the user to simulate discrete and continuous systems accurately and easily. Anything that can be imagined can be built using Extend libraries of pre-built blocks. No programming is necessary.

The software uses blocks, which are standardized libraries of process objects, to develop the models. A user can open the libraries and drag objects to a model's working space. There are different libraries built into the software to model discrete and continuous events, but the objects within the libraries are interchangeable with both types of the models.

The two main types of the blocks are *item blocks* and *attribute blocks*. Item blocks receive and process discrete events or items that pass through them in the model. Attribute blocks receive and process the attribute values associated with the items, but the items do not necessarily pass through these blocks. The data flow of a model is determined by the order of the connections between the blocks of the model.

I used Extend to model the final network structure I developed as well as the traffic types to be used with the resulting structure. Extend provided what I needed.

B. THE MODEL

I used a developmental approach in building my model because of the organizational outlook of the brigade. Starting with the general outlook of the brigade, I modeled the lower level formations and the connections between them. I then developed the interactivities of the formations with one another.

I expect to implement the network structure with a combination of the three main network topologies.

The first proposed model is an *All Star Topology* in which all the lines will extend from the Brigade Network Operating Center. At its center, there will be the main router to direct the network flow to the Battalion Level Nodes. Other routers at the battalion level which will direct the traffic to and from the Company Level Nodes. The Company Level Nodes will have hubs with sufficient capacity to connect workstations to the network. The topology at company level will be flexible so that the capacity might be increased to facilitate the connection of more workstations.

The second proposed model is a combination of star and bus topologies. The battalion level nodes will still be connected to Brigade Network Operating Center using a star topology. But at battalion level a bus topology will connect workstations from companies to the battalion level backbone. This will let the companies know when the backbone is available for transmission.

The third proposed model is a combination of star and ring topologies. In this model the battalions will be connected to the Brigade Network Operating Center with a star topology and the company workstations within the battalions will be connected using a ring topology. This model will allow the companies to know when the network is busy

and when it is available. Even if the network is busy, the companies will take turns to access the network.

The final proposed model is a combination of bus and the ring topologies. The battalions will extend their lines from a main cable (bus) which will extend from the Brigade Network Operating Center using a bus topology. The battalions will use a ring topology to establish the connections between the companies.

The recommended model is the *All Star Topology*. It provides a modular installment of the network. The Brigade Network operating Center will be installed first and then the network will be extended to battalion level . Also when something goes wrong with one part of the network or part of the battalion level network, the other parts of the network will not be affected. It will also make network maintenance easier.

C. THE RESULTING NETWORK MODEL

1. Overall Network Structure (ONS)

The overall network will have a backbone with a wide- bandwidth of 56 Kbps to go from one unit to another at the battalion level in the brigade garrison. There will be a main cable from which all other cables will source and go until the lowest level sub-unit.

The technology to be used is likely to be FDDI. Since there is a fiber structure being built, it will make things easier. But there is the problem of bandwidth. The ATM technology will surely provide a higher bandwidth. For this reason, the network is to be built in a way to allow quick switching from FDDI to a higher bandwidth technology.

2. Battalion Level Nodes (BLN)

These nodes will be the second level nodes. The upper level is the backbone and the lower level is the company level nodes. When the network is ready to be installed these nodes will be represented by hubs containing at least 20 sockets for 20 company level units.

The outlook of the network at this level will be star topology. The reason for choosing the star topology is the flexibility it will provide in terms of routing and maintenance. One branch from the router can continue working while another branch might be malfunctioning.

3. Company Level Nodes (CLN)

The company level nodes will also be installed as a star topology. But the companies will be flexible in choosing which topology to implement. Company A can have a star topology while company B has a bus topology. Provided that a company has the personnel to take care of maintenance and installation, it is free to choose a topology. Also the company is free to choose the technology such as TDMA, FDDI, and ATM .

D. DATA FROM THE MILITARY ORGANIZATION

The Network is developed for an imaginary brigade in one of the metropolitan areas of the country. It has 15 battalion level units and more than 60 company level

units. This will require up to 200 PCs to be purchased for the brigade as a whole. A detailed structure of the brigade is provided in Appendix A.

The terrain of the brigade location is mountainous with many hills . This might bring up some difficulties while laying cable to install the backbone. A detailed line routing map has to be developed before installing the lines.

Some of the sub-units of the brigade are in the same building . For this reason, the routing tables have to be developed before the lines are extended to the units. This also applies to hubs, which will be installed at lower levels for up to 20 PCs grouped together.

The *tempest-hardening* of the lines is also a concern. There are many ongoing communications with radios and phones. The networking lines has to be built with a sufficient distance from those communications lines so that they wouldn't be jammed altogether. The digging or hanging of the lines is also a detailed issue.

The personnel training is a vital factor in maintaining the network and the maintenance of any disorders. A detailed personnel training at all levels needs to be scheduled and made as soon as possible.

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IV. FINDINGS

A. THE RESULTING TOPOLOGY

The resulting network topology is All Star Topology. The reasons for this are already mentioned in the previous chapter. A detailed map of the resulting network structures is provided in Appendix B. The number of the required network equipment is also listed below. This is a preliminary list. A better result can better be obtained after a detailed Cost-Benefit Analysis.

LEVEL-UNIT	Main Router	Battalion Router	Hubs	Workstations
Brigade	2	0	0	0
Brigade Headquarters	0	2	2w/20sockets	25
Tank Battalions	0	2	10w/10 sockets	32
Mechanized Infantry Battalions	0	2	10w/10 sockets	32
Artillery Battalions	0	2	10w/10 sockets	24
Combat Support units	0	2	5w/10 sockets	22
Combat Service Support Units	0	1	6w/10 sockets	24
TOTAL	2	11	43	159

Table 4.1. Preliminary required network equipment

In the All Star Topology, at the center of the network is the Brigade Network Operating Center. From this center, the lines are extended to all battalion level units. There is the main router at the Network Operating Center. There is one router for each battalion level unit. The hubs will be located within the battalions. They will connect all the workstations at company level. The need for hubs' sockets might differ from one company or battalion to another. The number of workstations also differs at battalion level and brigade headquarters' level.

B. EXTEND VISUALIZATION MODELS

The following models are developed using Extend® simulation tool. Different traffic types such as network management applications, audio-visual teleconferencing,

www surfing, e-mail traffic, bandwidth delay are shown together with a top level diagram which shows the different connections at different levels. The following figures are sample processes for different traffic types.

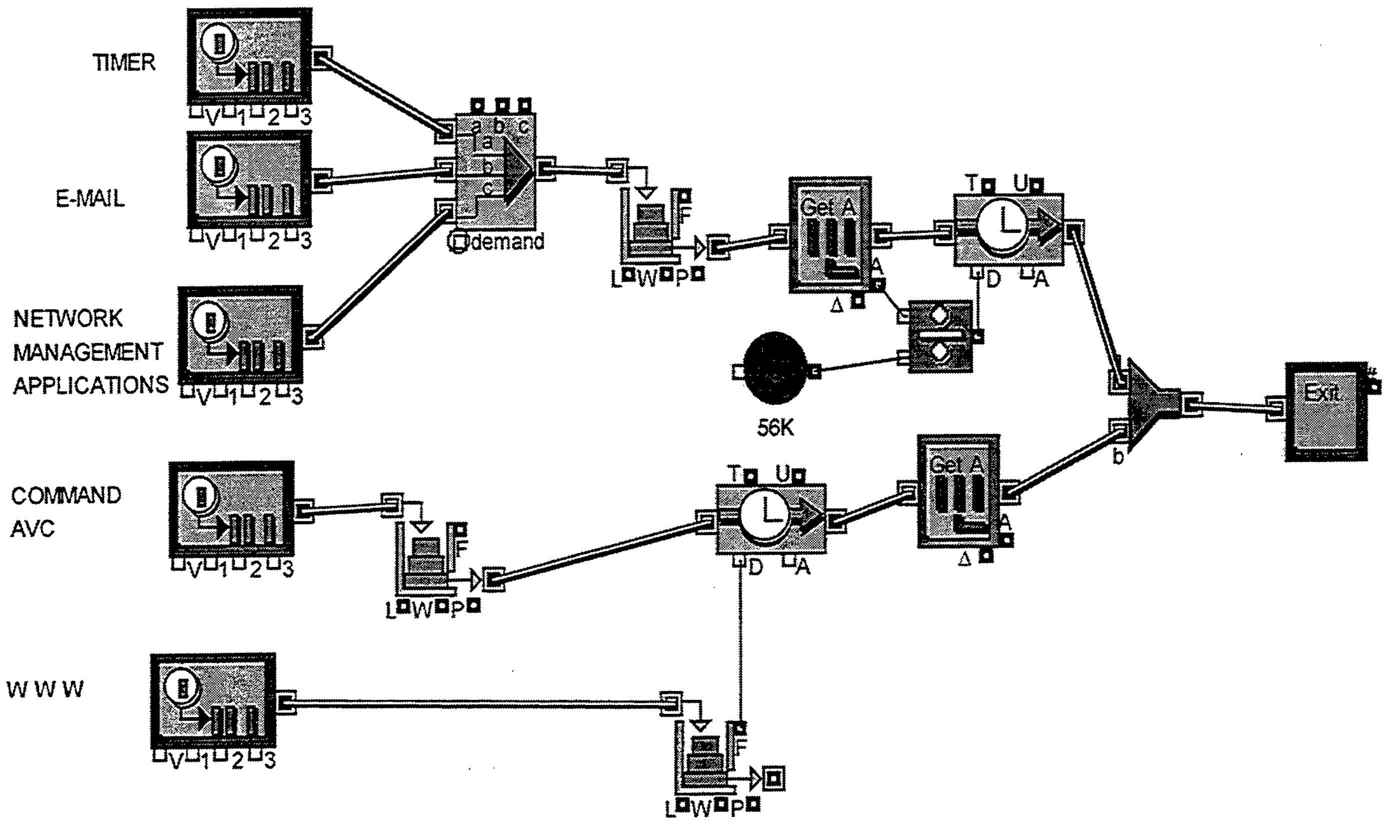

Figure 4.1 Combined Traffic Model

As seen in the model above the three different traffic types and timer are combined as a separate line from the other two traffic types. The reason for this is the command audio-visual conferencing and world wide web surfing will be only available to battalion commanders and upper command levels. After combining, the three traffic types undergo queuing processes according to their priority levels. That's why the queues are priority queues. After the queues are message delays. The message delay is equal to

the size of the message divided by transport bandwidth. The "Get Attribute" blocks represent the size of the messages and the destinations to which they are sent.

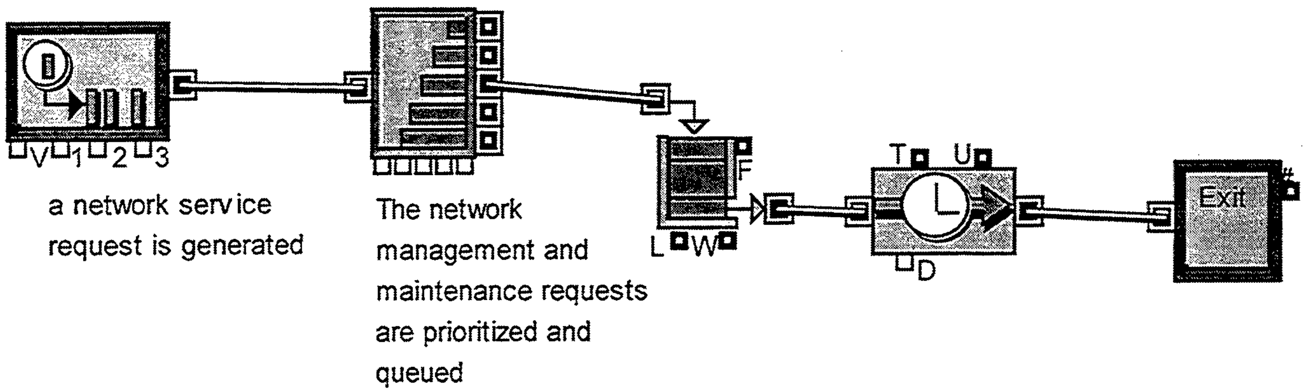

Figure 4.2 Network Management Applications

In the network management applications model a request for a network service is generated and then prioritized according to its emergency. They are then queued to be processed. There is an "Activity Delay" block to represent the service duration of the network service.

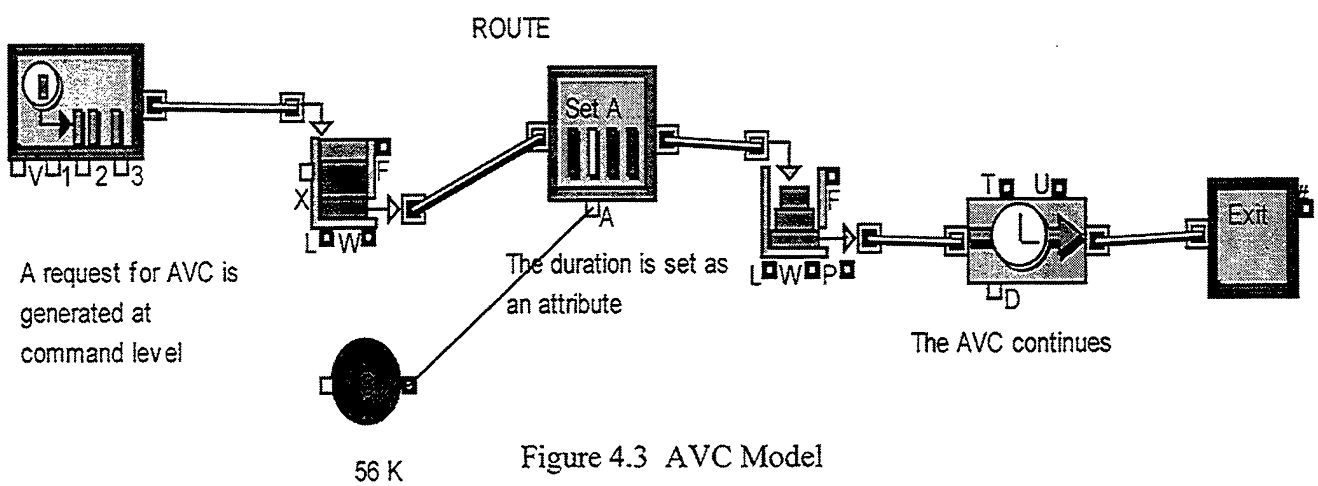

Figure 4.3 AVC Model

In Audio-Visual Conferencing model, a request is generated at battalion level commanders or upper level commanders. The request is then prioritized and the duration is set as an attribute with respect to 56 kilobytes transport bandwidth. If the line is busy the request is queued and when the line is available the AVC progresses and ends. The world wide web surfing traffic is subject to the same processes.

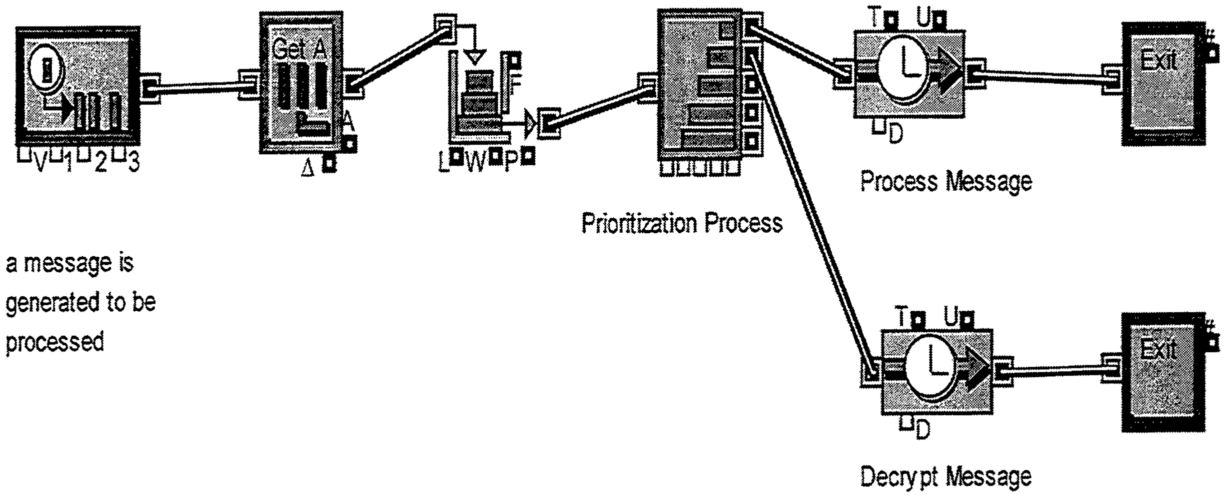

Figure 4.4 E-mail and E-mail with attachments Model

In this model an e-mail or an e-mail with attachment message is generated. The size and the destination is recorded by "Get Attribute' block for routing purposes. The messages are then queued and then prioritized. After prioritization there are two paths for messages to follow. If the message is an encrypted message it follows the decrypting path, if it is not an encrypted message it follows the path for regular processing.

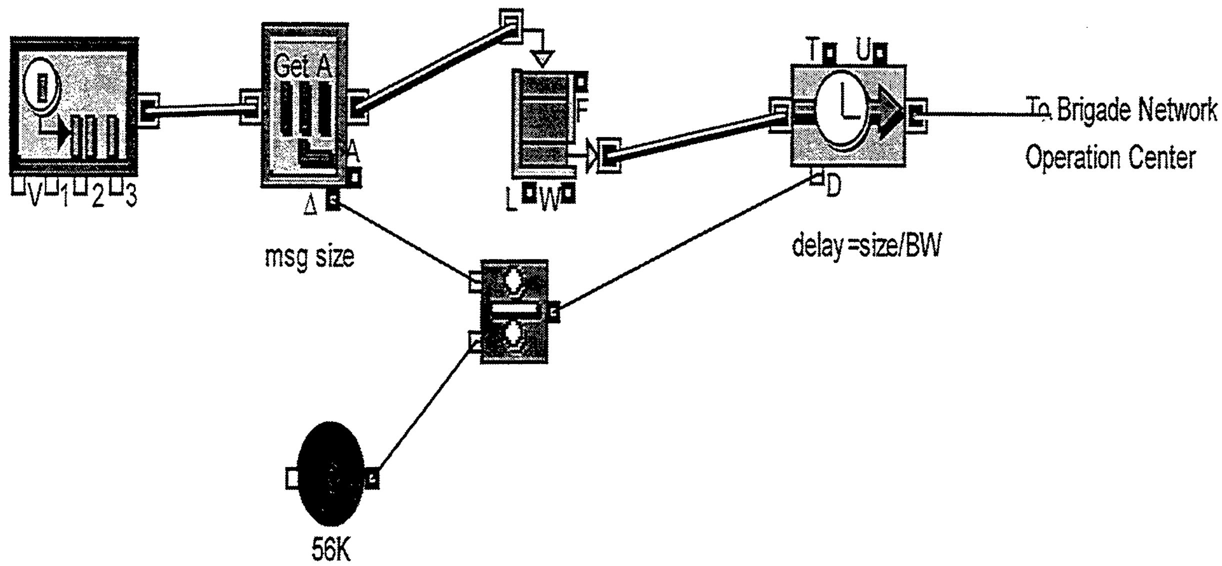

Figure 4.5 Bandwidth Delay Model

This is a model to show the bandwidth delay for any type of message. The delay is equal to the message size divided by bandwidth. Before delay messages are queued to be processed.

The detailed processes for different traffic types are provided in Appendix C. These two models are the running models which provided results of the complete network traffic with bandwidth delays. There are two parts of the main backbones which are fiber-backbone side and the auxiliary twisted pair side. The fiber backbone provides a bandwidth of 100 Megabytes and the twisted-pair side provides a bandwidth of 33.4 Kilobytes to 56 Kilobytes. The twisted- pair side is only to be used when something goes wrong with the fiber backbone side of the model. In the same appendix is the model of battalions. The battalion models are configured as a hierarchical block of the whole model used in the combined traffic model. Each battalion block represents all five

traffic types flowing through both the fiber backbone pipe and the twisted pair pipe. The total network load is compared to the capacity of the backbones. When the model is run there is no problem with the direction of the flow of traffic. But the model is run many times and as a result the network load increases and then the running stops. This is what we could achieve as a result of the whole model.

When the network is installed the preliminary measure of effectiveness will be the bandwidth and network load accordingly within the Brigade Network Operation Center and between all units and the opposite direction. This will take affect after the network is completely installed probably by using a network management tool.

The network protocols and the network technology combinations to be used with the Brigade Network are planned to be as follows:

Configuration	External to Brigade Network	Battalion Level Nodes	Company Level
01	IP	FDDI	F DDI
02	IP	FDDI	Fast Ethernet
03	IP	FDDI	Token Ring
04	IP	FDDI	ATM OC-3
05	IP	ATM OC-3	ATM OC-3

Table 4.2. Network Protocols to be considered at different levels

The protocols above will be tested and as a result an applicable combination of the protocols will be recommended. The first configuration will be tested first , the second will be tested second and so on. After all tests a final model will be installed. The testing processes should be done starting at the company level. As the recommended structure is compatible, the upper levels will be converted to faster technologies.

V. RECOMMENDATIONS

A. RECOMMENDATIONS FOR TURKISH ARMED FORCES

1. The Installation of the Brigade Network

A pilot brigade to implement the network should be chosen. Brigade Network Operating Center will be built. This center has to be installed by considering the enemy attacks, and will be somewhere in a hidden place. The structure of the current so called Communications Center is available to convert to Brigade Network Operating Center.

The network backbone should be installed. The fiber backbone being laid at present is available for this purpose. Lines will be extended to battalion level units. The routers will be installed for all battalion level units and the brigade headquarters. The lines will be installed for all company level units. The workgroups within the company level units will be established.

There will be Internet connections at the Brigade Network Operating Center. A private line will be provided to battalion commanders and headquarter branch commanders.

Once these are all done, the network will be ready to operate. All the necessary application tools for network management will be purchased and installed to run and monitor the network.

The personnel training will be an issue but this will be done by training the personnel at all levels. The responsibility of this training will belong to the Brigade Communications Company.

As a result there will no longer be any need for walking couriers within the brigade garrison. All messages carried by a courier will be sent and received via network. The load of the radio communications within and to outside will be reduced. The telephony traffic load will also be reduced. Simple e-mail messages will replace long telephone conversations. Shortly there will be lots of savings in all terms of communication means.

2. Follow-up Studies

a) Cost-Benefit Analysis

A detailed Cost-Benefit Analysis has to be made before beginning to install the network. This should be done after drawing the blueprints of the whole network structure. All the networking equipment should be counted and the costs will be calculated. The results might be compared to the costs of the physical human power and the brain power of the personnel.

b) Future Internet Connection

Once the network is established, the Internet connection of the network should be installed. Such a connection will provide Internet connections at all levels. This study will also include developing an intranet for the brigade together with a web site.

c) Compatibility Study

The compatibility study of the established network has to be made. This study would include all compatibility of bandwidth and transmission rates. The

infrastructure is being built with fiber. The structure is available within the brigade garrison and ready to install the connections.

B. RECOMMENDATIONS FOR DEPARTMENT OF DEFENSE OF U.S.

The model developed is for a brigade level military organization. It can be used for a similar organization either an Army or a Marine Corps Brigade. It can also be used for a comprehensive civil organization.

The technologies to be used with these organizations might differ from one to another. So before starting to establish the network, a compatibility study has to be made. The technologies to be used will differ. The study may include the application of ATM network instead of FDDI technology to the related organization.

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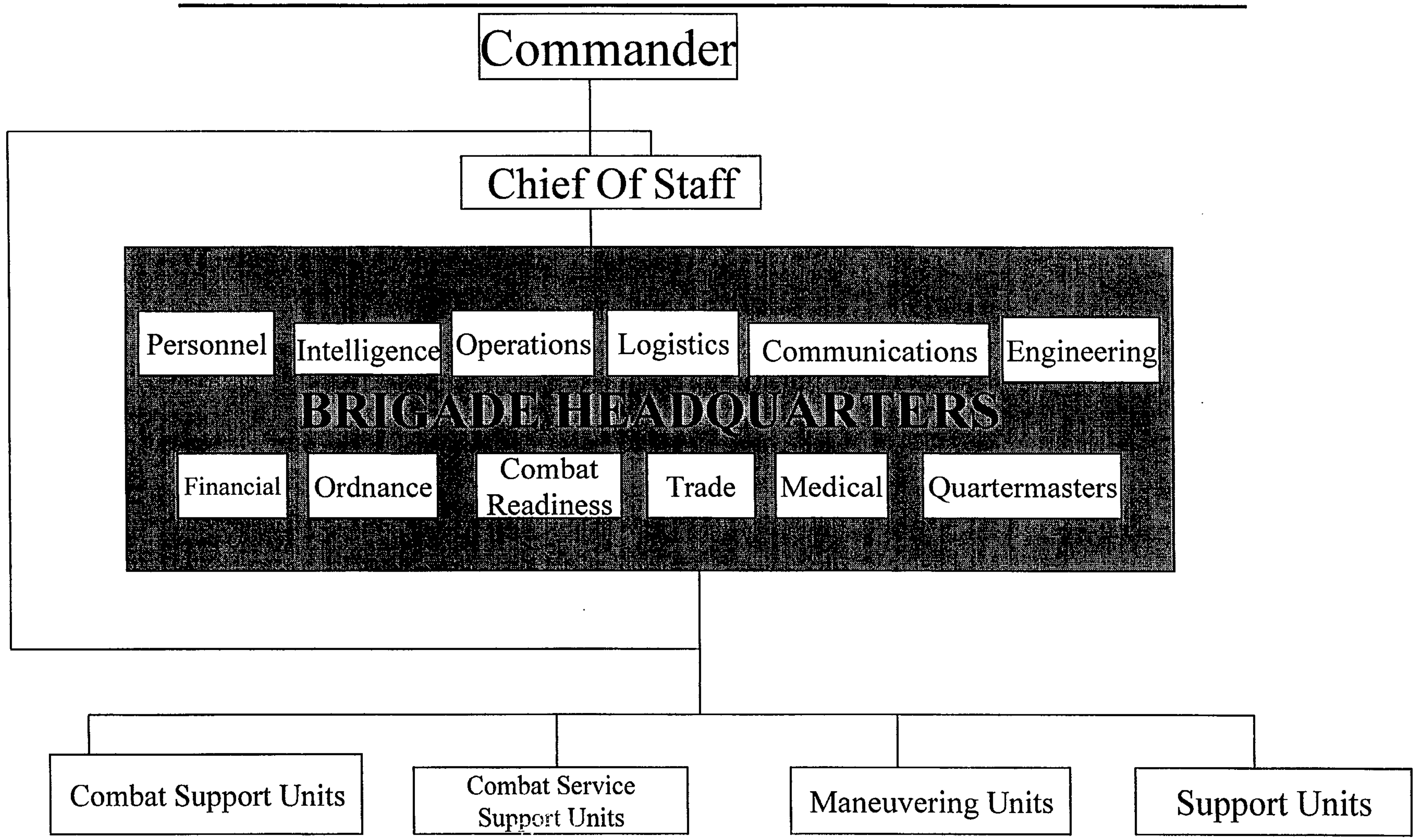
APPENDIX A. THE STRUCTURE OF THE BRIGADE

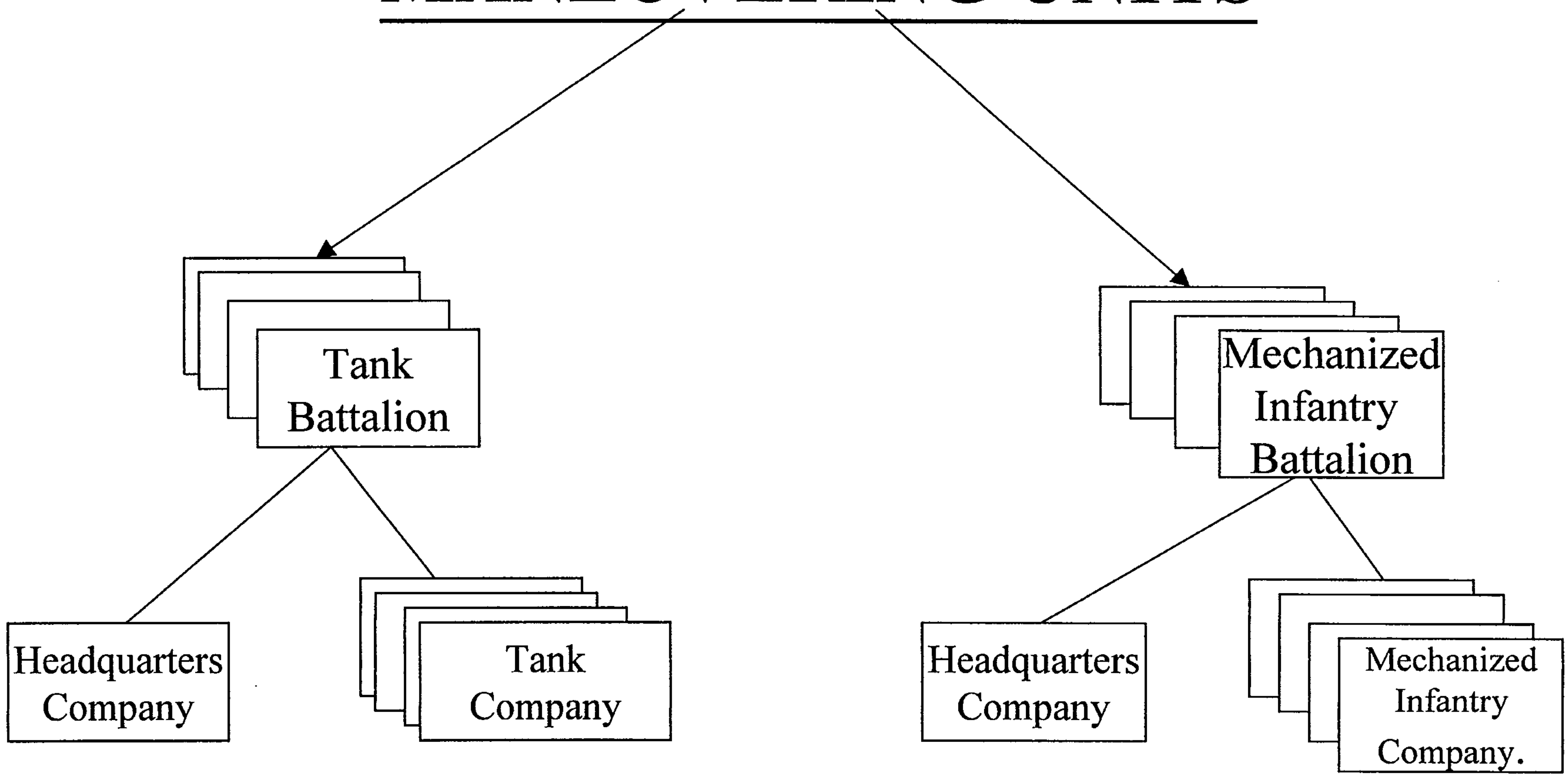
This appendix is the structure of the Brigade . It includes the structure of the sub-units. The following figures are contained in this appendix :

- The structure of the Brigade
- Maneuvering Units
- Support Units
- Command Support Units
- Command Service Support Units
- Tank Battalions
- Mechanized Infantry Battalions

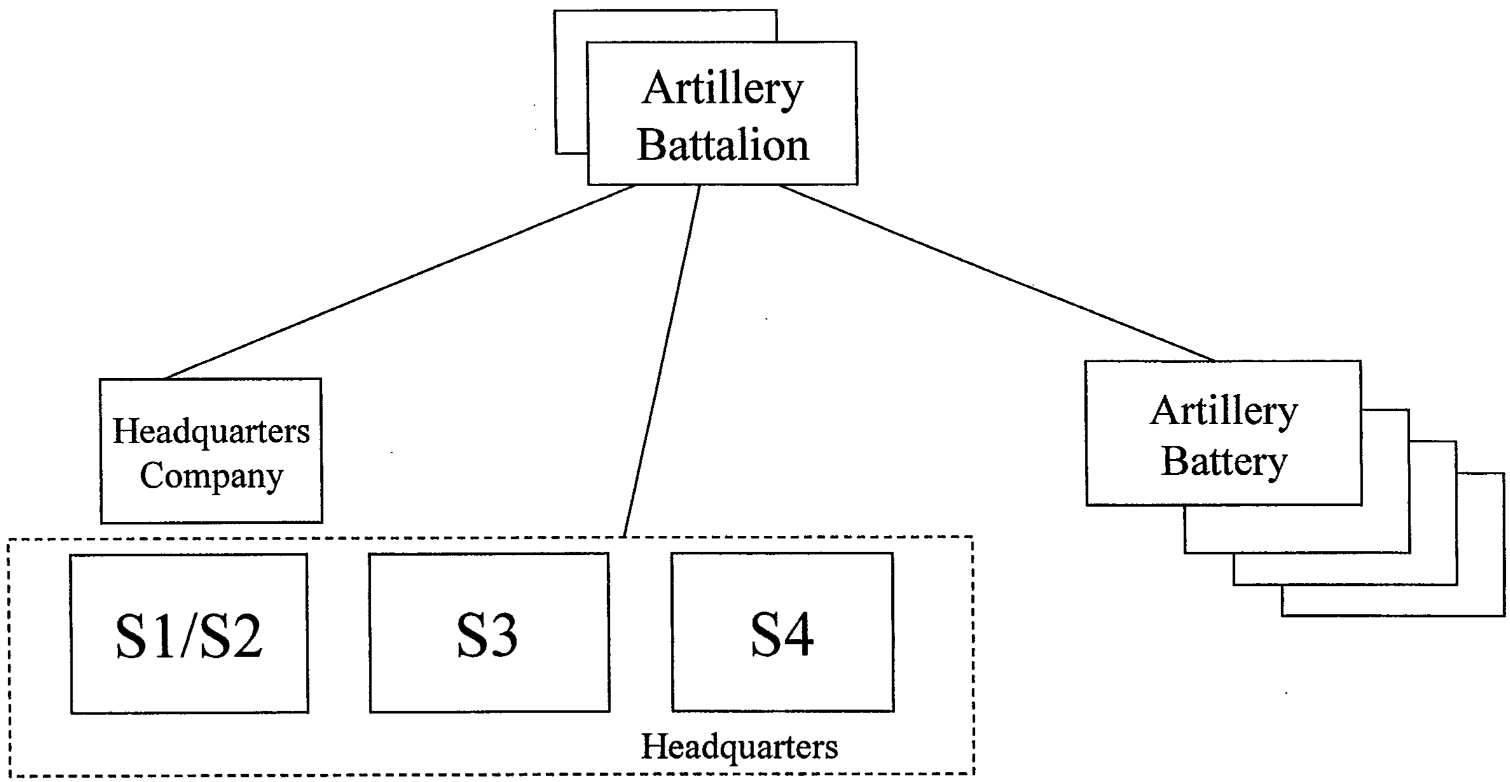
THE STRUCTURE OF THE BRIGADE



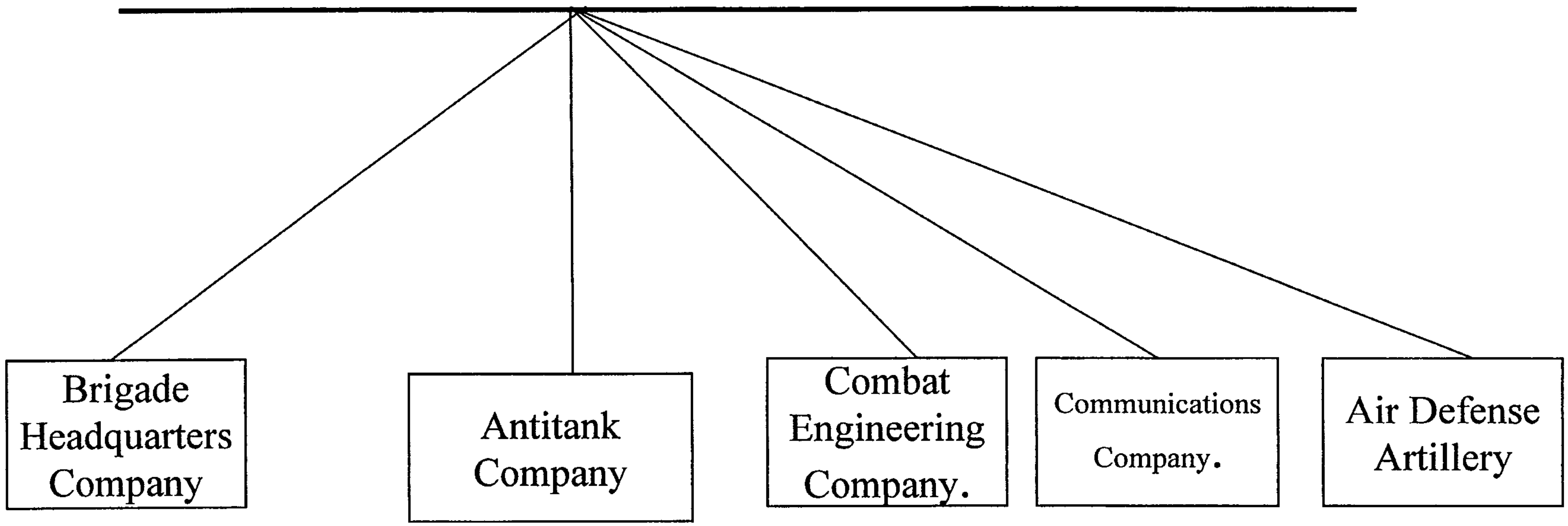
MANEUVERING UNITS



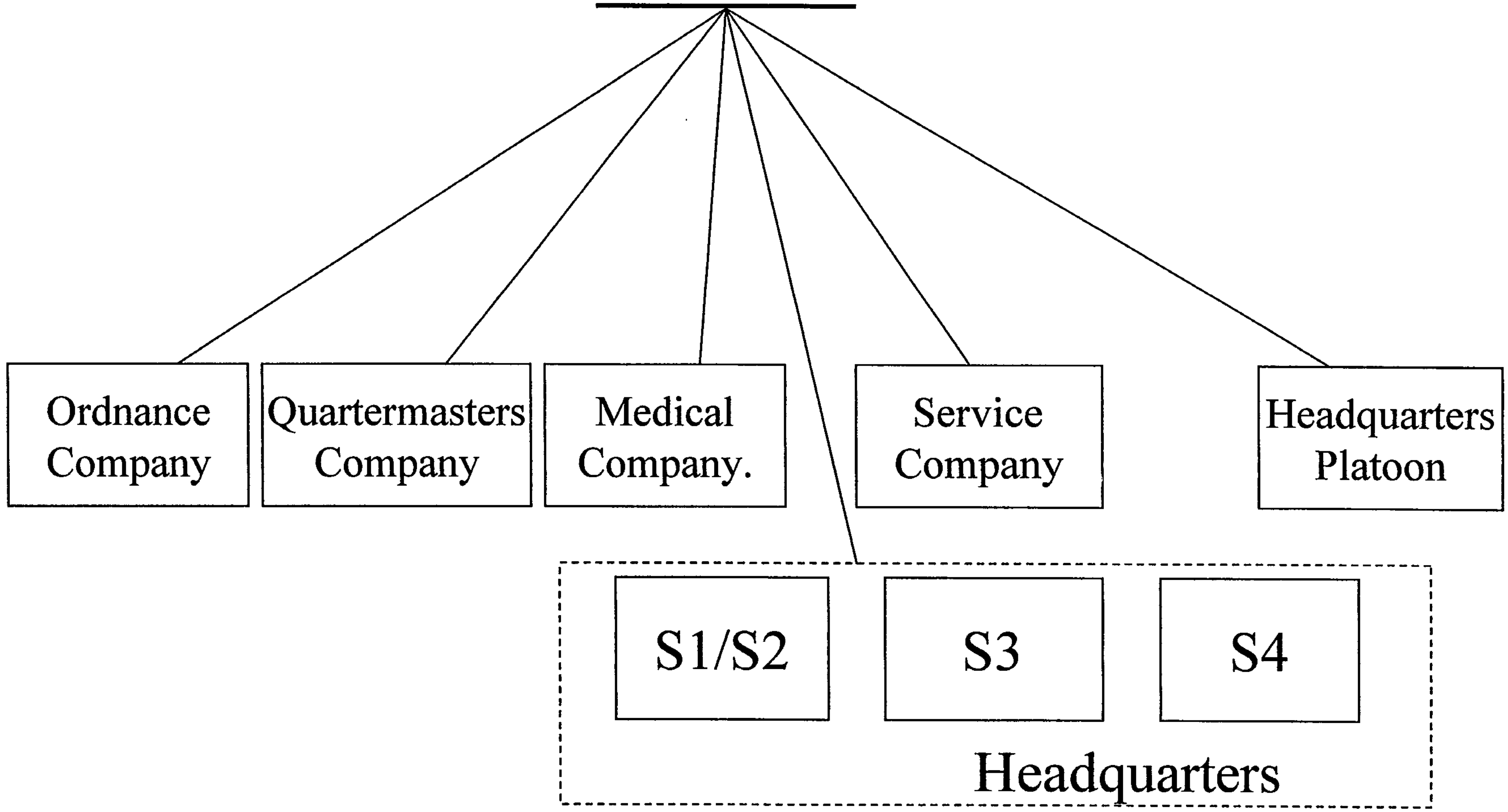
SUPPORT UNITS



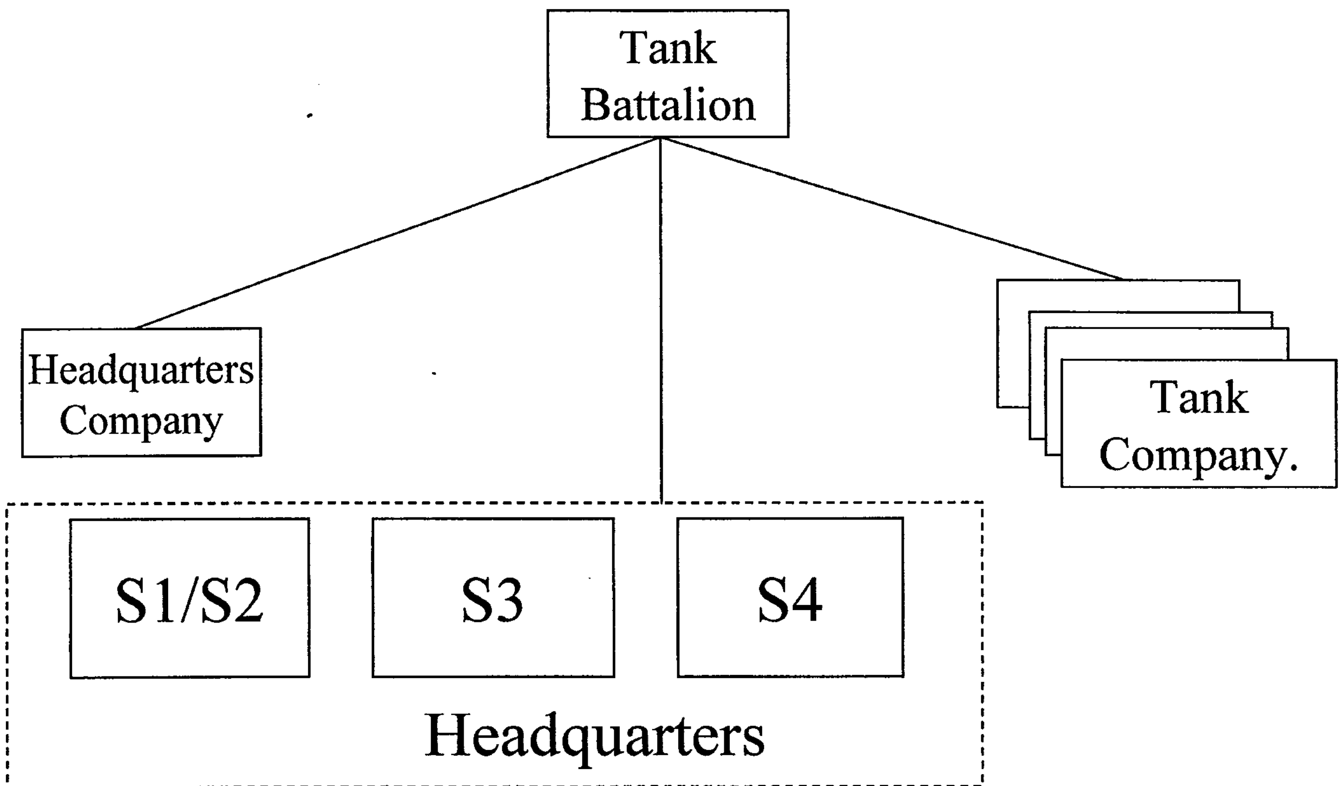
COMMAND SUPPORT UNITS



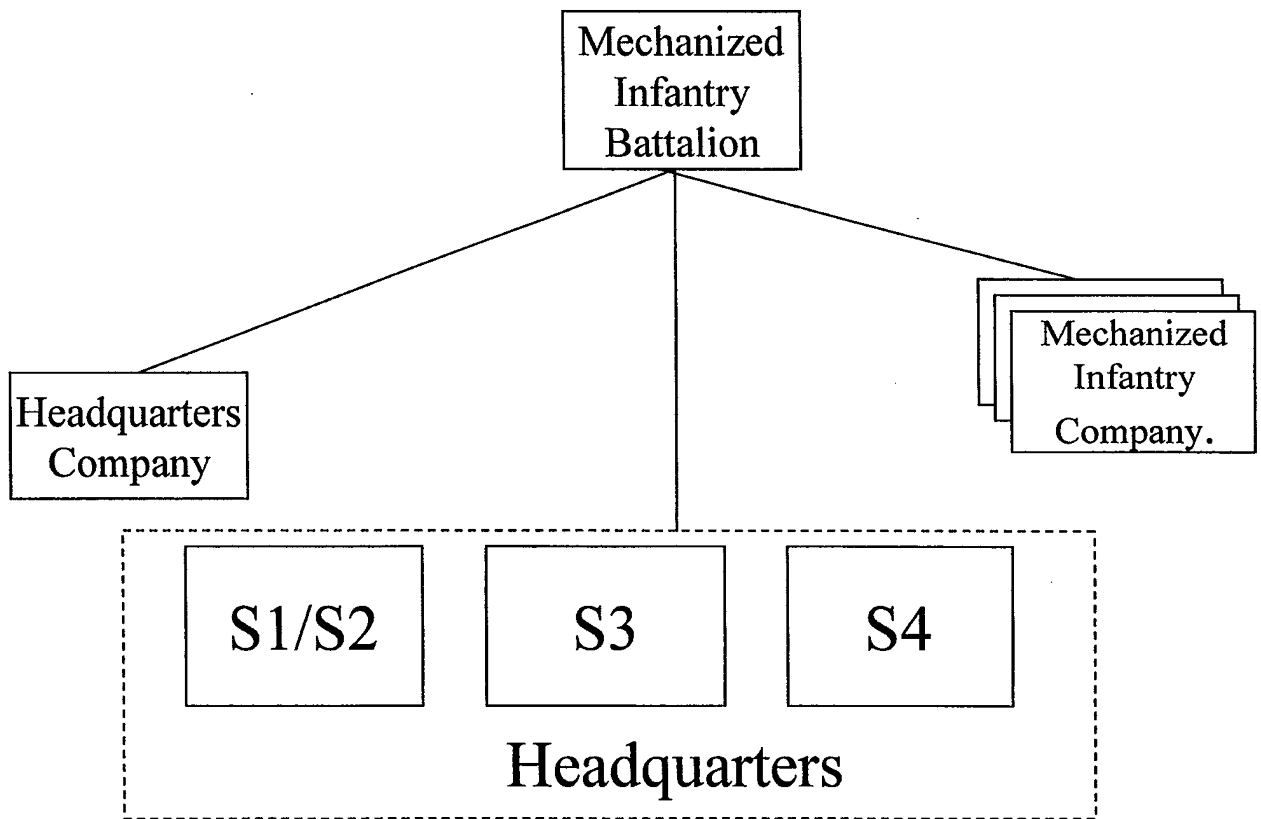
COMMAND SERVICE SUPPORT UNITS



TANK BATTALIONS



MECHANIZED INFANTRY BATTALIONS

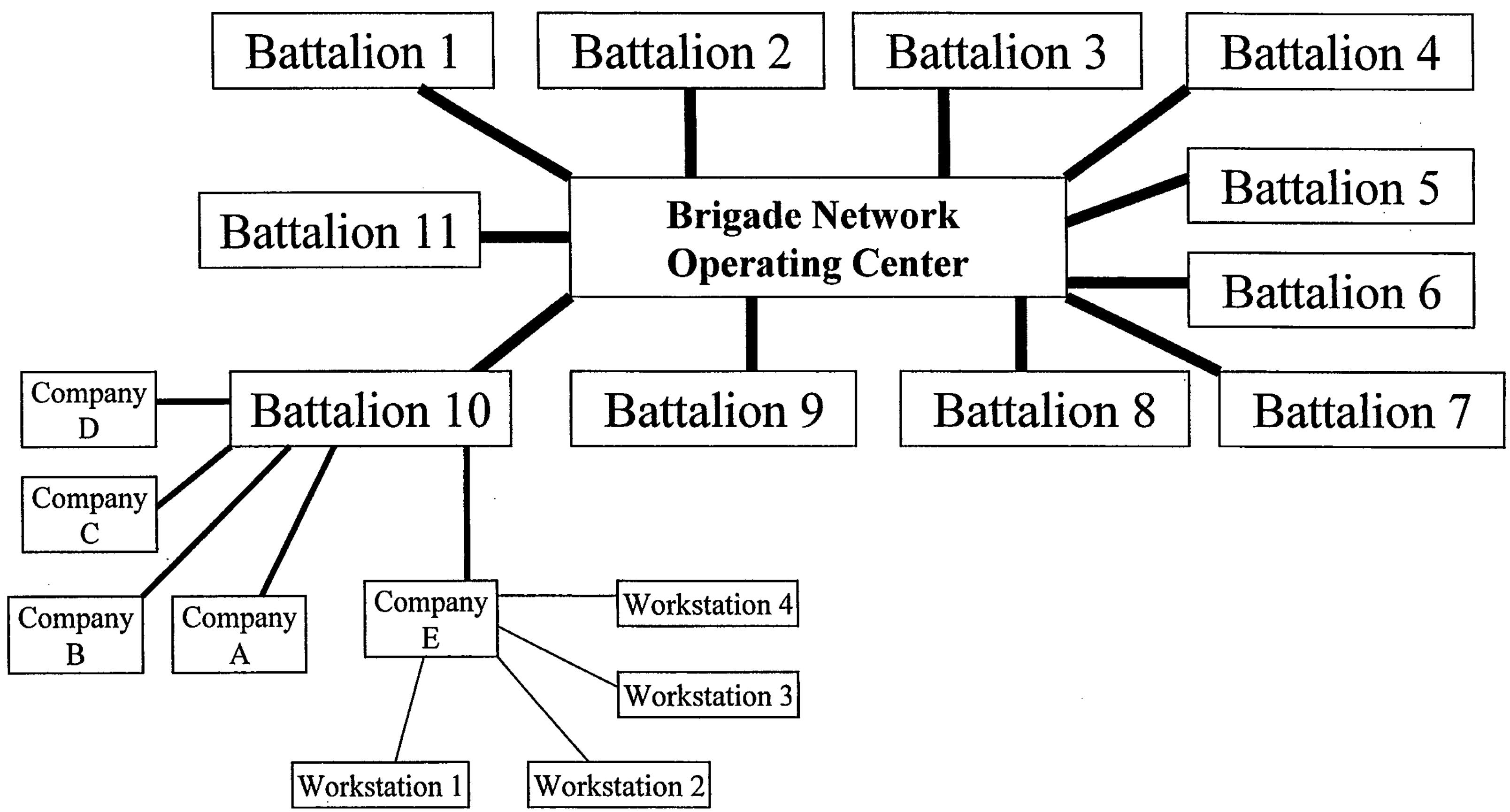


APPENDIX B. THE CONSIDERED NETWORK MODELS AND THE RESULTING NETWORK STRUCTURE

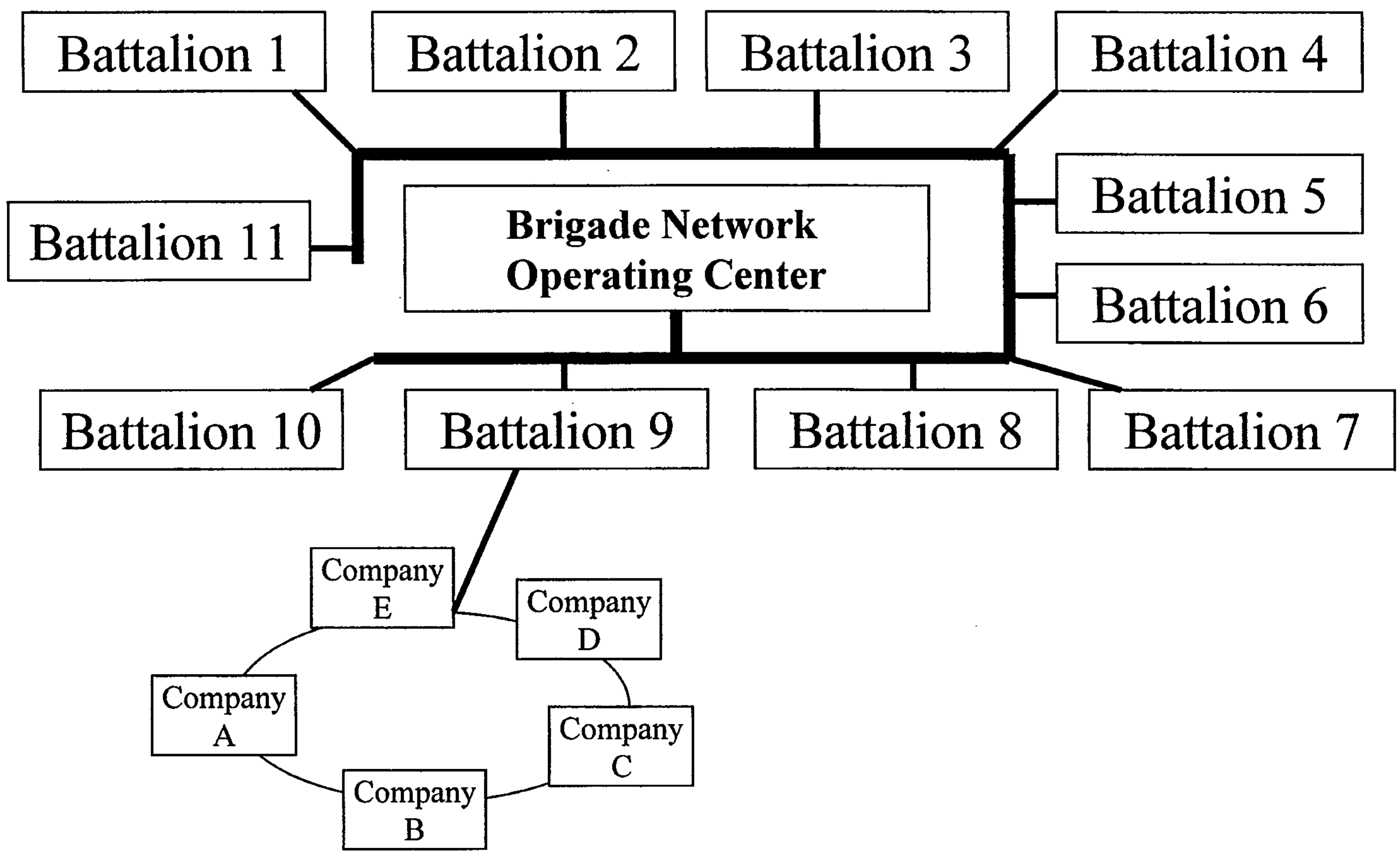
This appendix contains the different combinations of different network topologies for different levels of the Brigade. The resulting network structure is also provided. The following figures are included :

- All Star topology
- Bus + Ring topology
- Star + Bus topology
- Star + Ring topology
- Resulting Network Structure

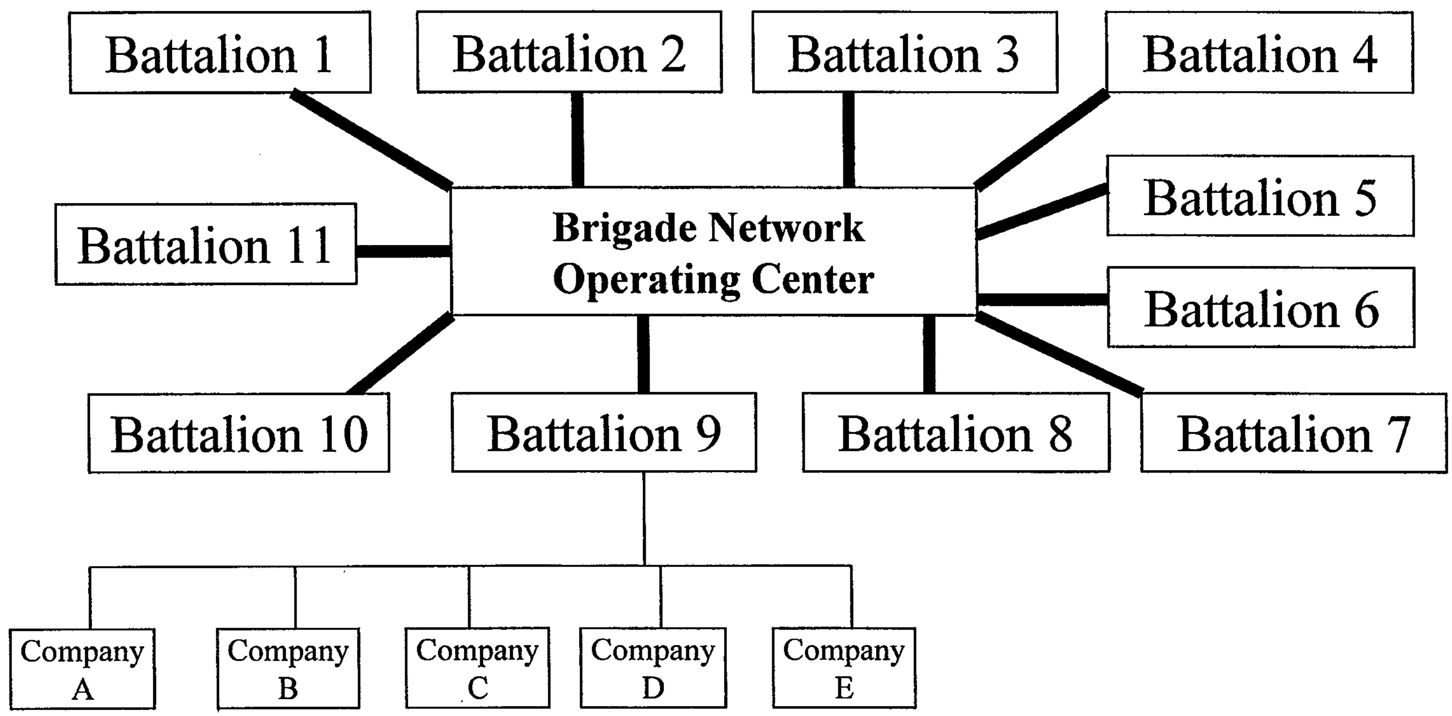
ALL STAR TOPOLOGY



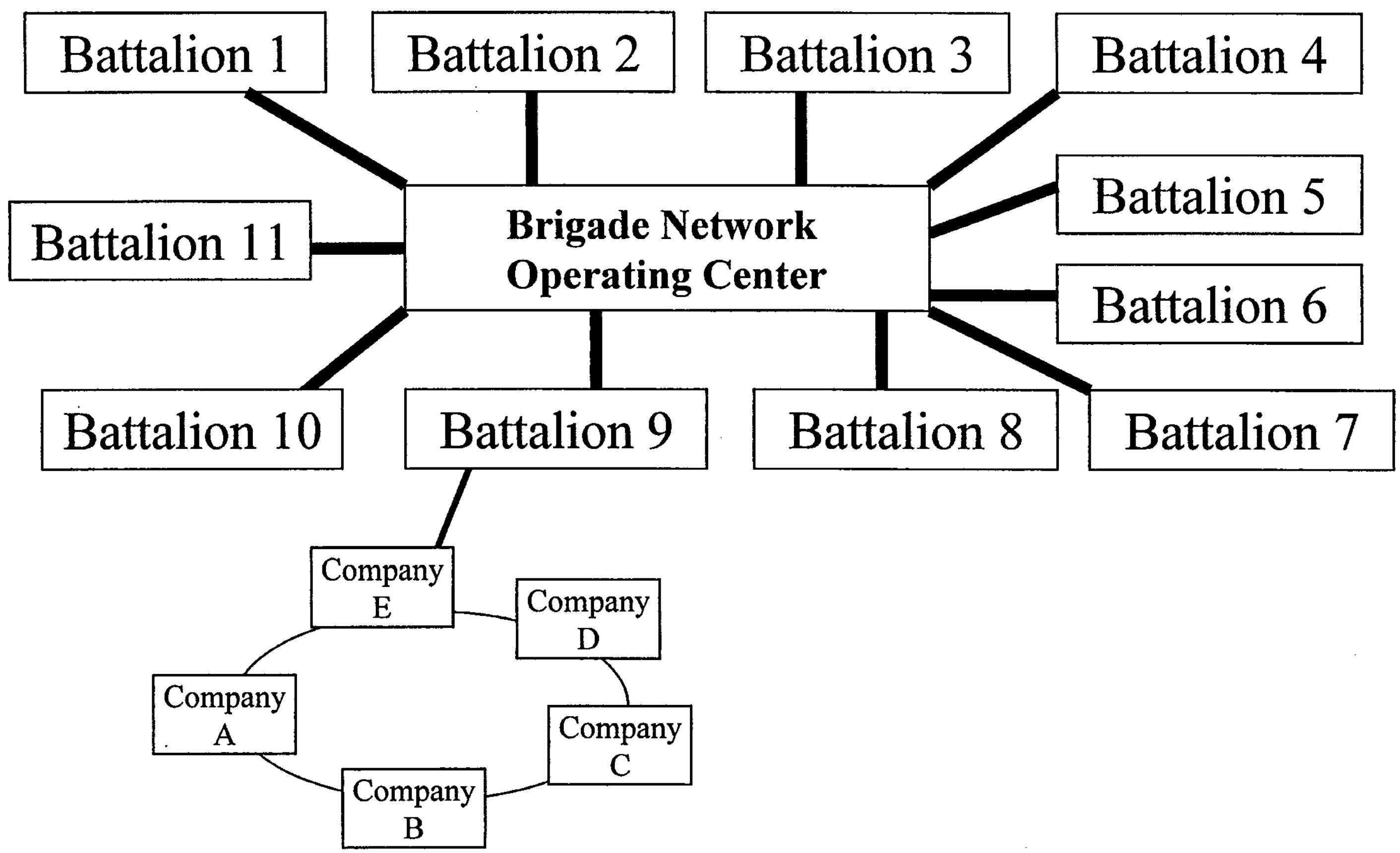
BUS+RING TOPOLOGY



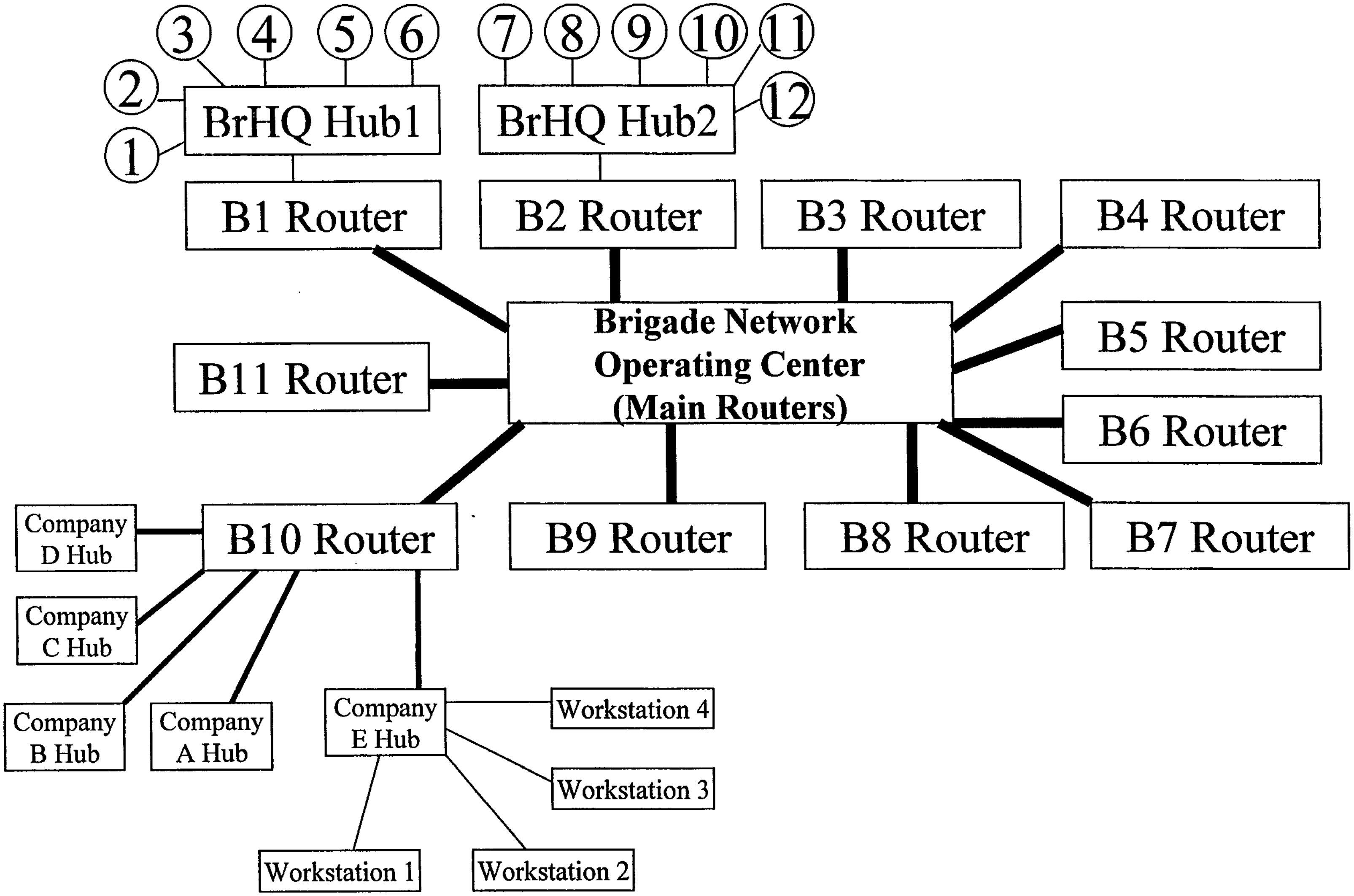
STAR+BUS TOPOLOGY



STAR +RING TOPOLOGY



RESULTING NETWORK

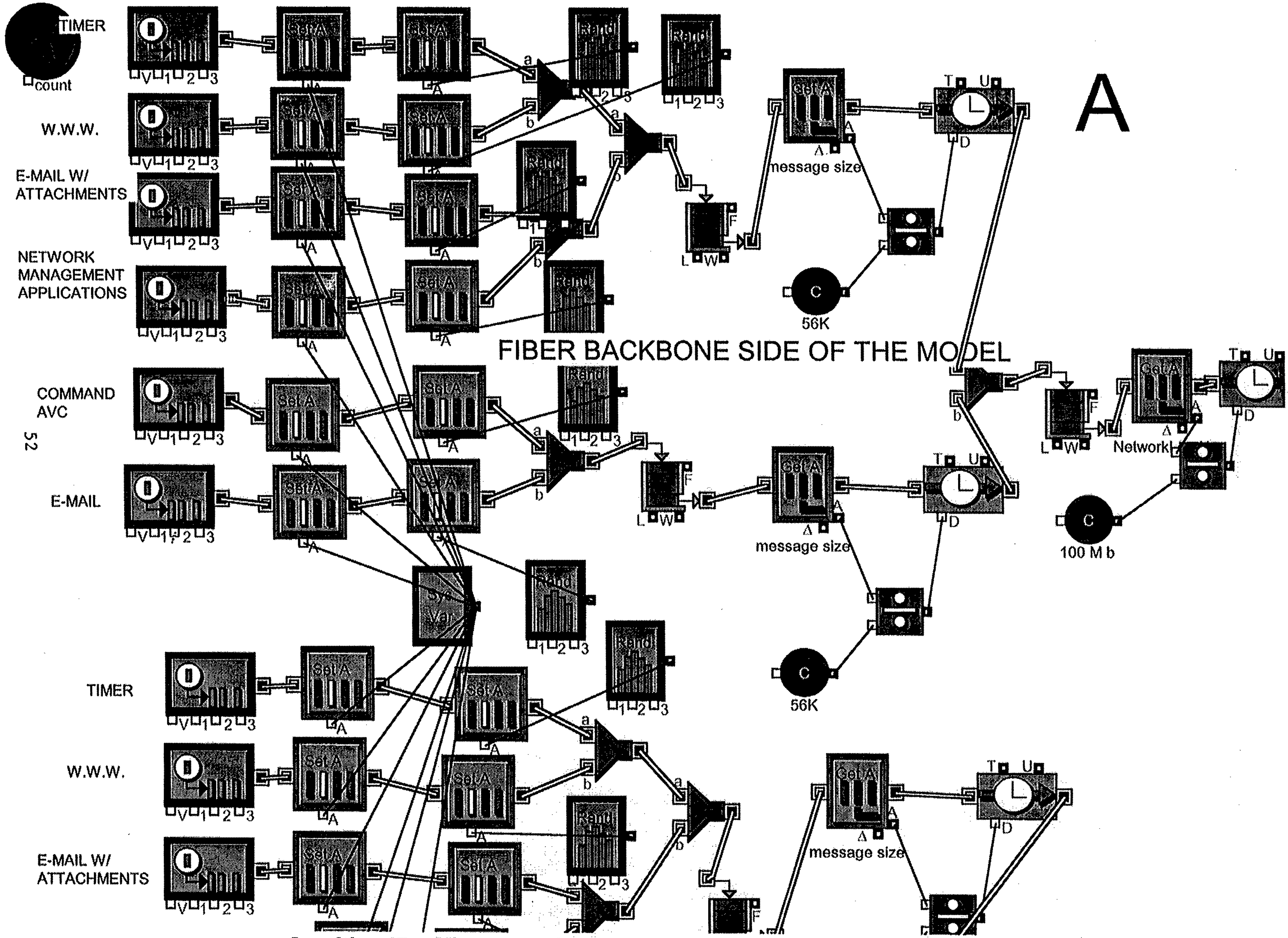


APPENDIX C. THE COMBINED EXTEND MODEL FOR FIVE DIFFERENT TRAFFIC TYPES

This appendix includes the Extend Model which represents the combined traffic types. It is of four pages. The map below should be used to combine the pages.

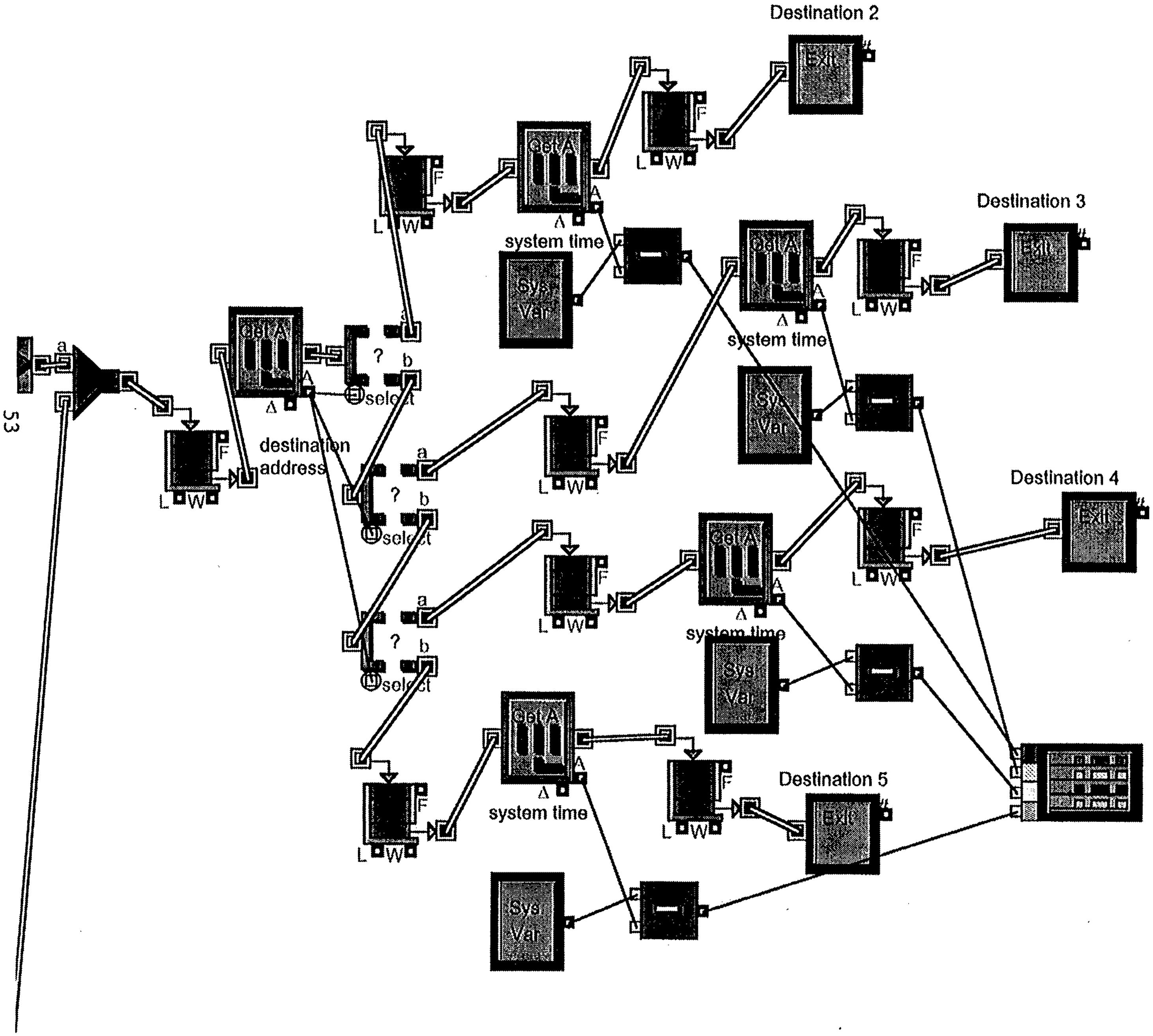
A	B
C	D

CombinedTraffic.mox

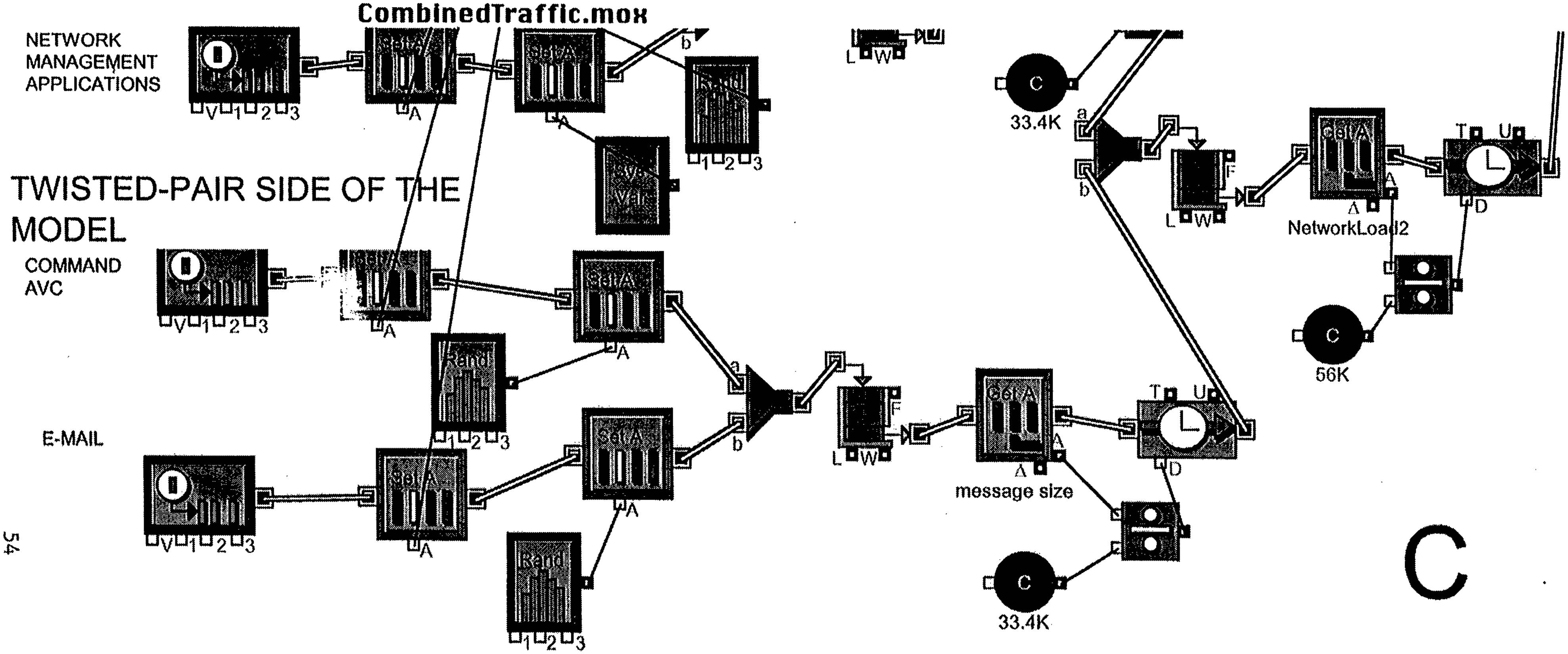


CombinedTraffic.mox – 1

B



CombinedTraffic.mox – 2


CombinedTraffic.mox
NETWORK MANAGEMENT APPLICATIONS
TWISTED-PAIR SIDE OF THE MODEL
COMMAND AVC
E-MAIL
Set A
Get A
Rand
33.4K
56K
NetworkLoad2
message size
C

D

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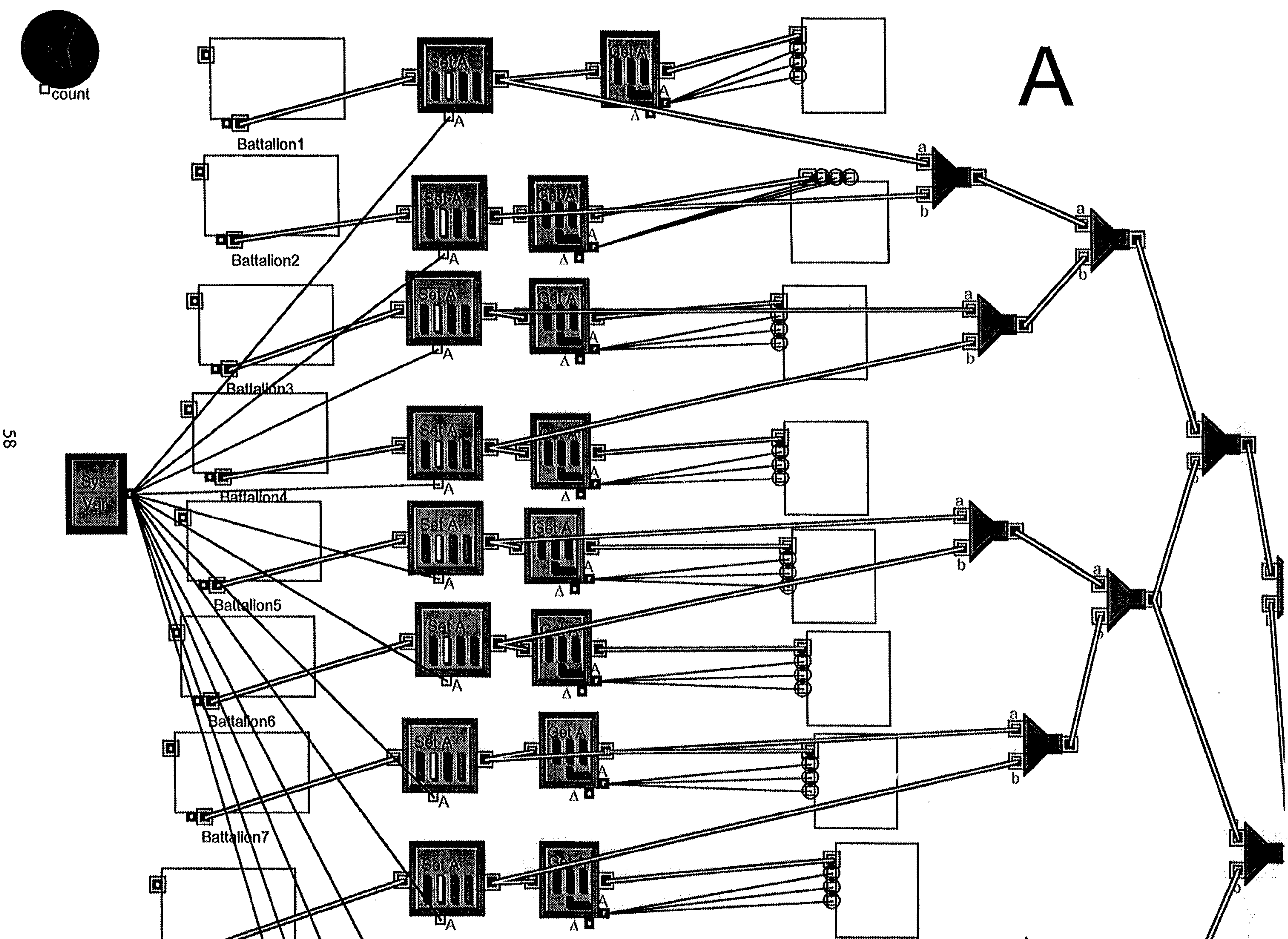
APPENDIX D. THE EXTEND MODEL FOR THE WHOLE BRIGADE

This appendix contains the battalions represented as hierarchical blocks. Each battalion block represents all five different traffic types shown in the previous appendix. The model is again four pages. The following map should be used to connect the pages.

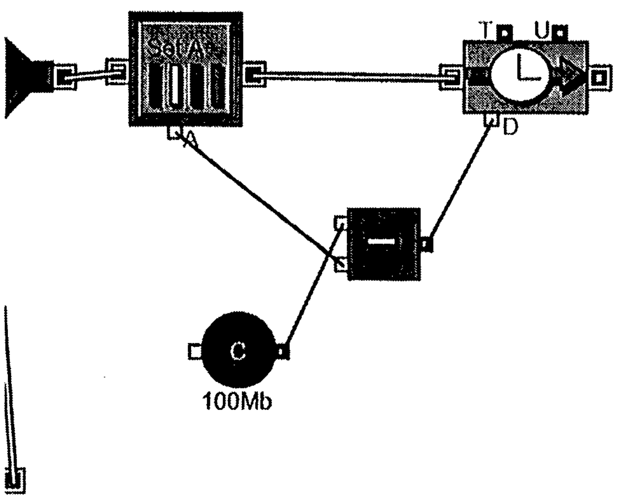
A	B
C	D

Battalions.mox



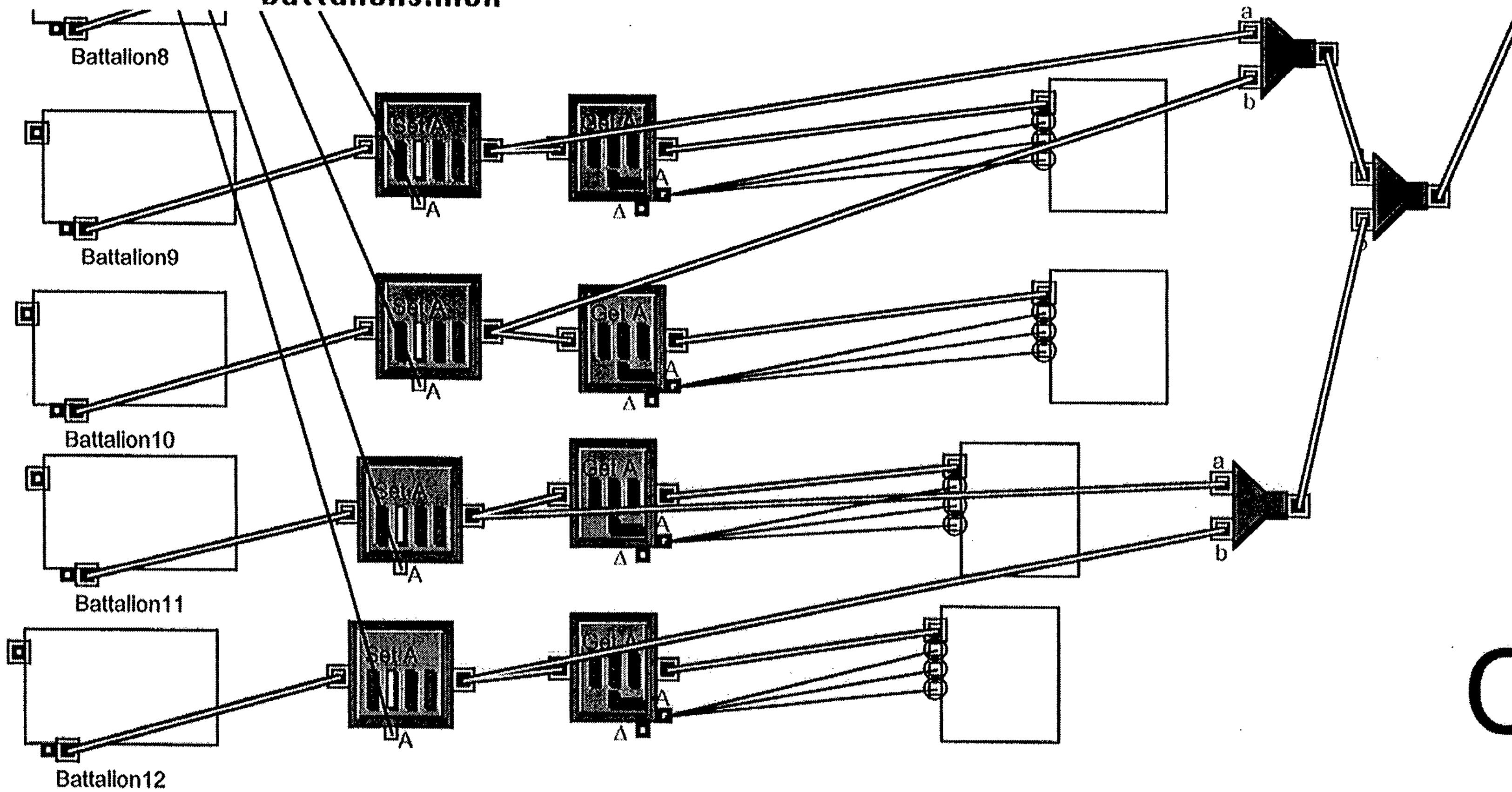
Battalions.mox – 1

B



Battalions.mox – 2

Battalions.mox



C

Battalions.mox – 3

D

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